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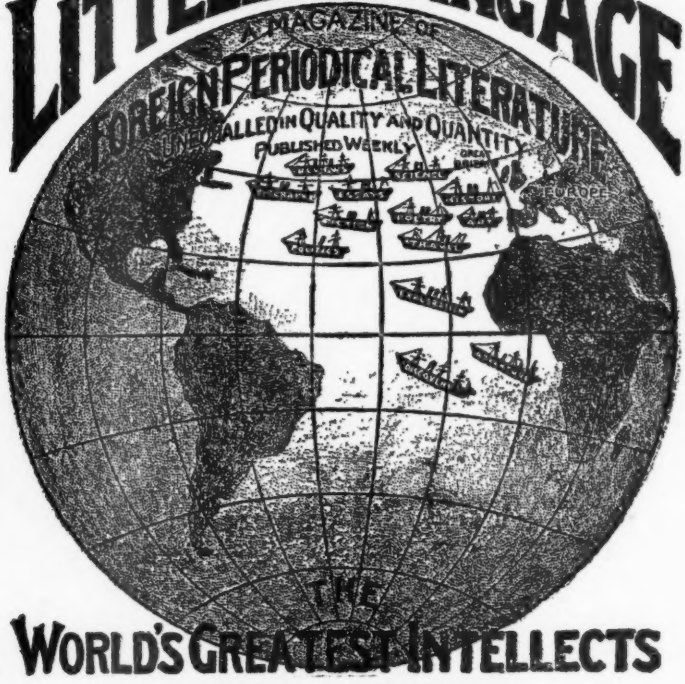

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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. XII. BOSTON, MASS., FEBRUARY, 1896. No. 10.

THE RAINFALL OF THE MALAY ARCHIPELAGO.

PROF. DR. A. WOEIKOF.

THESE islands, so near to the equator and so famed for their luxuriant and varied vegetation, are known to be very rainy. The fifteenth volume of the observations on the rainfall has appeared.*

They are published in full, *i. e.*, the daily sums are given, besides in every volume averages for the whole period appear, for the number of rainy days, the rainfall sums and the largest rainfall in the day of a month. I give below some averages, all in millimeters.

It has been long believed that near the equator the rains are everywhere heavy and of nearly daily occurrence. Yet actual observations have shown that this is not the case on the Atlantic on the high ocean as also on the island of S. Thomé (near W. Africa). At this station the months of June to September are very dry. On the Pacific, in American Polynesia, quite near to the equator, even all months of the year are very deficient in rain. The following table shows that on the Malay Archipelago both some of the rainiest and some of the driest stations lie within 1° 1/2 N. and 1° S. of the equator. The stations are arranged from west to east. The rainiest stations near the equator are on the west coast of Sumatra and in the mountains in its vicinity, but not all are rainy. Here we have without doubt the influence of the mountains. The more level Eastern Sumatra and Western Borneo have less rain, and less contrasts also. On the northeast of the peninsula of Celebes the rains

* Rainfall in the East Indian Archipelago, Batavia, 1894.

are comparatively light, and there is a well-marked dry season. At Gorontalo there is nearly as little rain as in the driest eastern part of Java, on Bali and Timor, and two to three months are very dry, if the temperature be considered. September has 1 1/2 inches of rain less than in the greater part of Europe and the Eastern United States. It must be borne in mind, besides, that these relatively dry stations are in the vicinity of mountains, on the shores of a very warm sea. Thus the equator has not always much rain, even in such conditions. The western coast of Sumatra and some parts of Borneo realize, to some part, what is often believed to be the rule near the equator.

TABLE I.

Latitude.		No. of years' observat'ns.	Rainy Days, Year.	Quantity of Rain in Millimeters.		
				Year.	Rainiest Month.	Driest Month.
0° 58′ S.[a s]	Padang.	15	178	4,579	Oct., 552	Feb., 254
0° 30′ S.[a]	Pad. Pandjang.[m]	15	251	3,805	Dec., 512	June, 176
0° 21′ S.[a]	Ft. de Kock.[m]	15	198	2,444	Mar., 268	July, 93
0° 12′ N.[a]	Ajer-Bandjes.[s]	8	157	3,110	Nov., 387	July, 178
1° 28′ N.[b]	Bengkalis.[s]	14	172	2,643	Nov., 376	June, 146
0° 56′ N.[c]	Tandj. Pinang.[s]	15	164	3,008	Dec., 378	Feb., 135
0° 55′ N.[d]	Singkawang.[s]	14	190	3,462	Dec., 504	July, 152
0° 1′ N.[d]	Pontianak.	15	183	3,262	Oct., 437	July, 163
0° 7′ N.[d]	Sintang.	15	209	3,801	Oct., 393	July, 234
0° 40′ N.[e]	Limboto.	13	112	1,820	Dec., 185	Sept., 48
0° 30′ N.[f]	Gorontalo.[s]	13	105	1,213	April, 143	Sept., 38
1° 20′ N.[e]	Masarang.[m]	13	185	2,467	Dec., 266	Sept., 109
1° 22′ N.[f]	Kema.[s]	13	129	1,500	April, 167	Sept., 61
1° 30′ N.[g]	Menado.[s]	15	186	2,704	Jan., 500	Sept., 86
0° 47′ N.[h]	Ternate.[s]	15	155	2126	April, 267	Sept., 108

a Sumatra, western coast and western mountains.
b Sumatra, eastern part.
c Riow.
d Borneo, west.
e Northeast peninsular of Celebes, inland stations.
f Northeast peninsular of Celebes, southern coast.
g Northeast peninsular of Celebes, northern coast.
h Island Teruate, eastern coast.
m Mountain stations.
s Coast stations.

In the following table I give on the same plan some data about the rains of Java, Southern Celebes, the Southern Moluccas and the islands to the south of Java, *i. e.*, of a region farther from the equator, 5° to 10° 1/2 S.

TABLE II.

Latitudes.		No. of years' observations.	Rainy Days, Year.	Quantity of Rain in Millimeters.				
				Year.	Rainiest Month.		Driest Month.	
6° 11′[a]	Batavia.	15	135	1,784	Jan.,	331	Aug.,	32
6° 36′[a]	Buitenzorg.	15	218	4,464	Jan.,	495	Aug.,	232
6° 50′[bm]	Sinagar.	14	217	3,177	Nov.,	378	July,	128
7° 11′[bm]	Kawah-Tji-Widei.	14	230	3,583	Jan.,	444	Aug.,	90
6° 51′[ds]	Tegal.	14	102	1,692	Jan.,	322	Oct.,	41
6° 53′[ds]	Pekalongan.	15	147	2,144	Jan.,	451	Sept.,	55
7° 6′[dm]	Pelantoengan.	15	210	4,897	Feb.,	622	Aug.,	97
7° 44′[fs]	Tjilatjap.	15	198	3,979	Nov.,	541	Sept.,	210
7° 34′[e]	Soerakarta.	15	130	2,166	Jan.,	364	Aug.,	44
8° 12′[fs]	Patjitan.	14	144	2,522	Nov.,	384	Aug.,	38
6° 42′[es]	Rembang.	15	102	1,409	Jan.,	243	Aug.,	20
7° 38′[gs]	Passoeroean.	15	92	1,254	Feb.,	284	Sept.,	5
8° 7′[h]	Loemadjang.	15	132	2,192	Dec.,	322	Aug.,	33
8° 3′[hM]	Kajoe Enak.	8	210	4,539	March,	508	July,	183
7° 44′[gs]	Probolingo.	15	85	1,126	Feb.,	216	Oct.,	7
4° 51′[i]	Pangkadjene.	15	152	3,744	Jan.,	821	Aug.,	24
5° 8′[is]	Makasser.	15	150	3,051	Dec.,	697	Sept.,	13
5° 33′[ks]	Bonthain.	15	120	1,316	June,	190	Sept.,	31
5° 7′[ls]	Balang Nipa.	15	150	2,512	May,	481	Sept.,	56
8° 6′[ms]	Boeleleng.	10	98	1,172	Feb.,	233	Aug.,	0
3° 42′[ns]	Amboina.	15	205	3,627	July,	648	Feb.,	111
8° 27′[o]	Bima.	13	88	1,175	March,	190	Aug.,	0
10° 20′[p]	Koepang.	14	79	1,438	Feb.,	383	July,	1

a West Java, northern slope.
b West Java, interior.
c West Java, southern coast.
d Middle Java, northern slope.
e Middle Java, interior.
f Middle Java, southern coast.
g East Java, northern coast.
h East Java, interior.
i S. W. peninsular of Celebes, western slope.
k S. W. peninsular of Celebes, southern coast
l S. W. peninsular of Celebes, eastern coast.
m Island Bali, northern coast.
n Island Amboina, Moluccas.
o Island Soembawa, northern slope.
p Island Timor, southwestern coast.
M Mountain stations.
s Coast stations.

It is seen that in general the rains are lighter in the east, *i. e.*, Eastern Java and also on Bali, Soembawa, and Timor, than in Western Java and Western Sumatra. In the same direction, the dry season gets also longer and sharper marked, so that the vegetation has a time of arrest corresponding to our winter. The sharpest contrast to that drier part of the Archipelago is on the western coast and western mountains of Sumatra. I have already shown that here the vicinity to the equator does not explain the heavy and equable rains, as Northeastern Celebes, just as near to the equator, has much lighter rains generally, and a well-marked dry season.

Even more marked is the difference between the interior of Western Java under 7° S., where the number of rainy days and the equable distribution of rains do not cede to Western Sumatra,

and the western coast of the southwestern peninsula of Celebes. Here the rains are also heavy, but how different the distribution! Excessive rains during the northwest monsoon, especially in December and January, and a very marked dry season. It reminds of the Malabar coast of India. Not even the rainiest stations of Western Java and Western Sumatra have so heavy rains in one month; the single places where we have observations in the Archipelago, and where anything approaching is to be noticed, are the Moluccas. But here the rainy season is the opposite, June and July, on account of the southeast monsoon impinging on the mountains of the Island of Ceram.

Only the following stations, with no less than 13 years' observations (there are in all 137 such stations), have in any month quantities of 600 mms. and above (roughly, above 24 inches): —

Pelantoengan, January, 601; February, 622; year, 4,497.

Oenarang (1), January, 609; February, 696; year, 3,973.

Segeri (2), January, 669; December, 743; year, 3,579.

Pangkadjene, January, 821; December, 765; year, 3,744.

Makasser, January, 695; December, 697; year, 3,051.

Amboïna, June, 624; July, 648; year, 3,627.

Saparoea (3), June, 638; July, 658; year, 3,564.

The last five stations do not belong to the very rainy, as to the yearly sums.

(3) On a small island, near Amboina.

(2) Western part of Southwestern Celebes, near Pangkadjene.

(1) 313 m. above sea level, on the northern slope of the Oenarang, Middle Java.

In the vicinity of the capital, Batavia, on the plains and towards the foot of the volcanoes Salak and Gedeh, on an elevation less than 900 feet above sea level, we have, —

Distance from Sea.	Height above Sea Level.		Rain, Mms.		
Kms.	Ms.		Year.	Jan.	Aug.
7	7	Batavia.	1,784	331	32
17	35	Passar. / Mingo.	2,447	384	59
33	92	Depok.	3,033	367	164
43	140	Bodjong. / Gedeh.	3,710	407	255
58	265	Buitenzorg.	4,464	495	232

This is a classical example of the increase of rain towards mountain chains and dense forests. The slightest increase is

experienced during the wet northwest monsoon, especially in January.

We have two other examples in the middle part of Java, of a very great increase from the northern coast to the northern slope of the mountains, but in these cases there are some sensible differences with the pair of stations, Batavia-Buitenzorg.

Distance from Sea.	Height above Sea Level.		Rain, Mms.			
Kms.	Ms.	Year.	Jan.	Feb.	Aug.	Sept.
0	4 Pekalongan.	2,144	451	365	76	55
19	693 Pelantoengan.	4,497	601	622	97	140
2	4 Semarang.	2,208	327	348	65	102
19	313 Oenarang.	3,973	609	696	114	96

Here the increase of the rains on the mountain slopes, over those near the sea-board, is even more conspicuous in the rainy than in the dry season.

The influence of the vicinity of dense virgin forests is seen by comparing Tjilatjap on the southern coast of Middle Java with two places on the northern coast, in the same meridian, Tegal and Pekalongan, both in the midst of large fields. All three stations are not very near mountains.

		Rain in Millimeters.			
	No. of Days of Rain.	Year.	Jan.	Aug.	Nov.
Tjilatjap.	198	3,979	313	219	541
Tegal.	102	1,692	322	43	122
Pekalongan.	147	2,144	451	76	118

Tjilatjap is on the lee side of the rainy northwest monsoon, the other two on its wind side, yet it is easy to see that Tjilatjap has double the quantity of rain of the stations on the northern coast.

The island of Celebes, in its southern part, gives us a good counter-proof, so to say, as to the influence of the wind and lee sides of the wet monsoon on the rains. Here the west coast is on the wind side, the south and east coasts on the lee side of the northwest monsoon.

		Rain in Millimeters.			
Latitude S.	Coast.	Year.	Jan.	June.	Aug.
5° 8′	W. (wind) Makasser.	3,051	695	130	14
5° 33′	S. (lee) Bonthain.	1,316	136	190	57
5° 7′	E. (lee) Balang Nipa.	2,512	123	461	145

The three places lie far enough from mountains not to be directly influenced by them. It is seen that in Celebes the

wind side of the wet monsoon is far more rainy than the lee side of the monsoon, contrary to what is the case in Java.

The greatest rainfalls per day call for special attention. Notwithstanding the rather great number of stations (137 with a length of observations of thirteen to fifteen years, and 197 in all) and the large yearly rainfall, the figures are far from reaching those of India and even of New South Wales and Queensland. Taking the above-mentioned 137 stations, there are only the following cases of rainfalls of 300 millimeters and above in one day in the years 1880 to 1887, and 1889 to 1893:—

Saporoea (Moluccas), July, 1890, 400.
Pandkadjene (S. W. Celebes), December, 1880, 399.
Bodjonegoro (E. Java), May, 1885, 370.*
December, 1887, 300.
Pelantoengan (Middle Java), February, 1893, 306.
Segerie (S. W. Celebes), January, 1882, 305.
Koepang (Timor), January, 1891, 303.

On the same day when the mentioned heavy rainfall fell at Segerie (11th of January), two other stations had also great quantities, Pangkadjene, 226, and Tjamba, 282 mms., and at the latter place besides, 290 mms. fell on the 12th, and 216 on the 13th of January.

Rainfalls of over 200 mms. (*i. e.*, roughly, over 8 inches), in one day, are much more frequent. Taking only the twelve years 1881 to 1887, and 1889 to 1893, and the 113 stations which have uninterrupted observations for the period, we have the greatest number of such cases at

Pangkadjene (S. W. Celebes), 8.
Saparoea (Moluccas), 6.
Amahei (Moluccas), Padang (W. Sumatra), } 5.
Tjilatjap (S. Coast, Middle Java), Menado (N. Coast, N. Celebes), } 4.
Tjamba (S. W. Celebes), Amboina (Moluccas), Patjitan (Middle Java), Banjoewangi (E. Coast Java), Koepang (Timor), } 3.

* Seems to be doubtful.

In the next table I give figures for entire regions of the Archipelago, and the above-mentioned years and stations. The first two columns need no explanation. In the third I give the number of days with a rainfall above 200 mms., multiplied by 100 and divided into the aggregate number of years of observations at all the stations, or the percentage of such cases. In the fourth column the mean rainfall for all stations having thirteen to fifteen years' observations. First I give the figures for three great geographical regions, of which the first comprises the islands in the southeast of the Archipelago, principally Java; the second, the great islands of Sumatra and Borneo, with the islands between them; and the third, Celebes and the Moluccas. Next, the same figures for smaller regions. The division line between West and Middle Java is 108° 40′ E., and between the latter and Eastern Java 111° 20′ E. At last I give separately the figures for the great province of Preanger, in Western Java, on the southern slope of the island, with two stations to the north of the volcano of Gedeh.

The table gives also a good insight into the mean rainfall of the regions, so far as observations reach. The actual average will probably be higher as mountain stations are found, but in Java and Western Sumatra, it is well known that the rainfall in the mountains is generally heavy.

	No. of Stations.	Total No. of Days with over 200 mm.	The same in 100 years' Observations.	Mean yearly Rainfall, mms.
The whole Archipelago	137	98	6.0	2,519
Java, Madura, Soembawa, Timor	77	33	3.6	2,362
Sumatra, Borneo, etc.	36	23	5.3	2,876
Celebes and Moluccas	24	**42**	**14.6**	2,490
Western Java	24	4	1.4	2,760
Central Java	27	16	4.9	2,603
Eastern Java and Madura.	24	9	3.1	1,778
Soembawa and Timor	2	4	16.7	1,307
Western Sumatra	12	14	9.7	3,014
Eastern Sumatra	10	2	1.7	2,636
Riow, Banka, Billiton	6	4	5.6	2,884
Borneo	8	3	3.1	2,960
Southwestern Celebes	9	20	**18.5**	2,650
Northern Celebes	7	6	7.1	2,030
Moluccas	8	**16**	16.7	2,713
Preanger and Gedeh Group	15	0	0	2,980

The percentage of days with a very heavy rainfall is far from being everywhere in accordance with the yearly rainfall. Southwestern Celebes has by far the greatest percentage, and the yearly rainfall is but slightly in excess of the average for the Archipelago. Preanger has a rainfall much above the average, and no case of a rainfall above 200 mms. per day in twelve years, while in Western Sumatra the highest rainfall coincides with a high percentage of heavy rains in one day, and in Eastern Java and Northern Celebes a rainfall much below the average with a small percentage.

I have mentioned but a few facts which can be found in the important publication mentioned. Thick nets of rain stations are to be found in many countries of Europe, and in some in America and Asia, but the mode of publication leaves mostly much to be desired, as only the monthly sums, the quantity falling on the rainiest day, and the number of rainy days are published; the rainfall net of England does not even give so much. The rainfall net of the East Indian Archipelago was the first (1879) (together with the French) to publish the rainfall observations in full, and but few have since followed their good example, the most notable being the Indian.

I must also mention a map of the island of Java, which appeared with the observations of 1891, with the location of all stations and forest zones, the latter divided into three classes. I have published an extensive study of the rainfall of the East Indian Archipelago (1) to which I refer for more details. It contained the means of eight years only.

(1) Regen des Malayischen Archipels, Zeitschrift der Oesterreichischen Gesellschaft für Meteorologie, 1885.

PSYCHROMETER STUDIES.

PROF. H. A. HAZEN.

IN the December JOURNAL, Dr. Ekholm has reviewed the problem of the psychrometer mostly in the light of experiments with a stationary psychrometer, coupled with a few theories as to the behavior of water vapor and ice vapor. The singular fact is that he ignores the really vital points in the discussion and touches only a pure theory relating to a side issue. Readers interested will find this discussion in the following numbers of this JOURNAL: July and December, 1894, and February, 1895. I had very much hoped that Dr. Ekholm would continue his experiments, as he proposed to do, and thus bring himself out of the cloud of vapor in which he has become enveloped.

Dr. Ekholm says that in some experiments a water bulb and an iced bulb thermometer were placed side by side in a vacuum and certain results obtained. It is much to be regretted that any experiments of this kind were ever tried for scientific accuracy. It is necessary in such work to boil the water for hours in order to remove all air. Surely no one should deliberately use such crude attempts in bolstering his view on such delicate points.

In the last article Dr. Ekholm's great contention is that the vapor pressure of ice is less than that of water, and he devotes three pages to elucidate this point which is admitted by every one. Since it is impossible to keep ice at exactly 32°, it is necessary in such experiments to maintain the temperature just a fraction below 32°, and under these circumstances it is found that experimentally the vapor pressure is the same over ice and water. Now Dr. Ekholm entirely fails to see the bearing of this point. He finds that at about 25° Fahr. the ice-covered bulb reads, in saturated air, about 0.3° higher than the dry, and at 30° Fahr. he obtains almost exactly the same result. He ascribes this to a condensation of water vapor upon the ice, and assumes that this could take place because at the lower temperature water vapor has a pressure .127 mm. greater than ice vapor, and at the higher temperature it has a pressure .053 mm. greater. I submit that if this theory were true he should have had a gradually

diminishing difference between the dry and ice bulbs as the temperature rose, and the fact that the difference was nearly the sme at 25° Fahr. and 30° Fahr. is fatal to his theory. Again, if Dr. Ekholm will try his experiment (in fact, I think he did get a few results) at exactly 32°, or a fraction below, in saturated air, he will find almost exactly the same difference as at 30°, and I am sure he will admit that his theory must fall in that case, for all are agreed that at 32° the difference between the pressure of the two vapors is insensible. But this is not all; this beautiful theory is dependent upon a single point, and that is that in a perfect vacuum, *the vapor pressure of ice is higher than that of water because there is a continued condensation of water vapor upon the ice.* I doubt if there ever were so curious a theory to explain a fact of this nature. If this means anything, it is that in some way there is an accession of water vapor over the ice, for if there were not, the water vapor would be very quickly condensed upon the ice and the effect would cease from a lack of vapor. I do not know that any one has ever determined just what causes the greater pressure of water vapor over ice vapor, but one thing must be plain and that is that it cannot possibly be due to such a theory as this of Dr. Ekholm's. I will hazard the opinion that in the last analysis it will be found that the constitution of or the molecular paths in the water vapor are of a different order from those in the ice vapor, and this accounts for the difference.

It seems to me that after eliminating the effect of the pressure of ice and the irregularities in using a still psychrometer nearly all of the trouble that Dr. Ekholm had may be very easily explained, and it is only on this basis that all his results can be harmonized. He has stumbled over two points; the first is as follows: At temperatures from 25° to 32° Fahr., in saturated air, he finds the ice-covered bulb always reading higher than the water-covered, and the difference between the results at 25° and at 32° is not very marked, showing a common cause acting at those points and not a cause which can by any possibility vanish at 32°. The second stumbling-block is the fact that when he used a thin metallic shell to protect his bulb from ice pressure he obtained a *higher* reading than the bulb having the ice pressure. This result was so extraordinary that I do not see why he did not at once comprehend that all his theories must fall to the

ground. Here was a bulb which had *no* compression reading *higher* than one which had a compression. We can put these two stumbling-blocks together and find a common cause acting in all these cases which will harmonize all the difficulties. It is well known that a polished glass surface has a different absorption from a muslin surface for reflected heat and bright heat, also there is a difference between ice and water and between a metallic covering and a glass covering, and this would hold true in the latter case even though both were covered with ice. Here there is a common cause acting in all these cases to make one bulb read higher than the other.

If Dr. Ekholm will put his dry iced and water-covered bulbs in a tin vessel with water at the bottom, having only the stems outside, I feel sure he will find them reading alike, at least I have never found any difference in scores of experiments. Dr. Ekholm admits that with a ventilated psychrometer the ice-covered bulb agrees exactly with that having water. Surely here, if anywhere, his beautiful theory about ice and water vapor ought to apply, and, since he admits that it does not, he virtually gives up the whole contention. Some one may wonder why reflected heat or bright sun heat will not affect the ventilated psychrometer. It will do so unless carefully protected, but the effect is very slight if there is a good ventilation in a shaded place.

Dr. Ekholm tries to make a point in that in helping him out of his difficulty I stated that, if the outside of a film of water could freeze first, there might be a slight compression when the water nearer the bulb was frozen and expanded against the outer film even at 30°, whereas I had before stated that the contraction does not become appreciable till a much lower temperature was reached. There is no contradiction here when my exact words are read instead of a garbled extract.

As to an addition of weight to a block of ice in a saturated air, I do not see any difficulty. On Greylock, in Massachusetts, on one occasion, I found a temperature —7° Fahr. The air was saturated, and yet there was no vapor visible on the mountain. In a very few minutes after reaching the top, my black coat began to have little dots of white upon it, and in a short time I was covered with these little frost particles, too small to be seen unless a score or so were piled on top of each other. The same

would be true in every saturated air, or, better, supersaturated air. Surely there was no *condensation* of vapor in this case.

If it be in order, I would like to ask a few questions of physicists.

Is it possible for any vapor of a substance at any temperature to *condense* upon that substance if the vapor temperature is *lower* than that of the substance?

After a substance and its vapor have each reached an equilibrium of temperature in an absolute vacuum, can any of that vapor condense upon the substance with liberation of latent heat, especially if the substance has a *higher* temperature than the vapor?

Is it possible to consider for a moment that there can be an evaporation or a condensation in saturated air, especially if the substance is respectively colder or hotter than the air?

Is it possible for invisible frost particles to exist in the air, which may be deposited upon or adhere to a substance without condensation and liberation of latent heat?

Dec. 13, 1895.—The more one studies these theories the more is he surprised. Regnault, in all his formulæ, introduces a sudden jump at freezing because the latent heat of evaporation of ice is greater than that of water, thus causing the ice bulb, theoretically, to always read lower than the water bulb. Now comes Dr. Ekholm and *exactly reverses* all of Regnault's theories by peculiar theories of his own, whereby the ice bulb is made to read higher than the water bulb. Of course both of these theories cannot be right, and it behooves Dr. Ekholm to straighten out the tangle. We may be sure that the mechanical theory of heat will not be shaken by crude experiments with a stationary psychrometer. Prof. Ferrel found that the iced bulb, when well ventilated, read slightly higher than the water bulb, and the explanation he gave was that the iced bulb was not sufficiently ventilated (this explanation unfortunately does not explain). Is it not astonishing that with all his almost perfect knowledge of this whole problem and all the elements that enter it he did not hit upon this unique theory promulgated by Dr. Ekholm. The fact remains that he was perfectly satisfied that no sudden jump occurs at freezing, and he introduced none into his final formula.

I have been fortunate in having access, for nearly a week, to

the latest form of the Assmann aspiration psychrometer. The thermometers are marvels of delicate construction, and when most carefully tested showed no error greater than .1° C., and in the working part of the scale no error at all could be detected. In this apparatus there is a double tube for the circulation of the air. The inside tube is perilously near the bulb. It is very essential that no shred or thread of muslin touches the metal. I worked several hours before I could obtain even approximate results. The rubber tube used for wetting the bulb is practically worthless, for it fits so closely that the overflowing water strikes the side of the tube around the thermometer, and no result can be had till all that water has first evaporated off; by that time the muslin itself is in danger of becoming dry. The wet bulb always reads too high, giving two to three per cent too great relative humidity, even at moderate degrees. The cause for this is made up from those sources of error, though I cannot at present determine which is the most potent, probably the last.

First, The metal is so near the bulb that, even at moderate dryness, its temperature, 10° to 15° higher than the bulb, must affect that.

Second, The space between the bulb and the metal is so excessively small that the upper part of the wet bulb must always remain in an air current almost saturated with moisture.

Third, The air current is so weak that even with the clockwork wound to its extreme limit, there is not enough ventilation. This last source of error would be specially active whenever there was ice on the bulb. There is no instrument that can compare with the sling psychrometer for portability, ease of handling, and accuracy. If one wishes to use the latter in bright sunshine, it may be done perfectly by joining the thermometers side by side and by keeping their plane at right angles, to the circle of whirling, each thermometer being protected by a tube of paper or aluminum bent at the lower end at right angles so that the stream of air rushing in at the mouth is deflected at an angle past the bulbs.

JAN. 16, 1896.

CURRENT NOTES.

*Meteorology in the University.** — The atmosphere presents to us a purely material and mechanical aspect, and it is this which rivets the attention of the physicist, properly so-called. He views the storm thundering over his head, the floods devastating the earth, the droughts destroying the crops, the hurricane lashing the ocean, and asks, Is there not order and law in the midst of this confusion? It is for such a physicist, for the meteorologist proper, for him who would understand the daily weather map and would predict the weather from day to day on a rational basis, as the engineer predicts the performance of his unbuilt engine or the chemist the behavior of some novel untried combination, that I would plead. Such a student needs a collegiate course that shall fully recognize dynamic meteorology as one of the subjects in which candidates for the degree of "Doctor of Philosophy" may prepare for examination. Thus you will solve the problem as to what Columbia College can do to provide for the meteorological needs of this country. The mere statement of these subjects — the three lines of type that show the student what he may study if he will — serves as a sufficient stimulus, if his bent is in that direction.

I maintain that there is a real demand for a broad course of instruction in meteorology, and that there is an abundance of work to be done, both mathematical and experimental. The courses and the laboratory work that bear on the study of the atmosphere are almost the same as those that one would naturally take up if one were preparing to be a hydraulic engineer. The fundamental question to be resolved in the study of the mechanics of the atmosphere consists in determining what the general motions of the air must be under the influence of gravitation and the rotation of the earth; of evaporation and condensation of moisture; of absorption and radiation of heat, and of the irregularities of oceans and continents, hills and valleys. If there were no solar heat the temperature would be fairly uniform at all altitudes, the earth and the sea would be frozen, there would be no clouds, and the atmosphere would be a stagnant layer revolving with the globe to which it adheres.

Prof. William Ferrel, a native of Pennsylvania, was the first to solve approximately the equations of motion and deduce some of the phenomena which, as observation shows, actually exist. He proved that any free body

* An extract from a report by Prof. Cleveland Abbe, presented in 1893 to Pres. Seth Low, of Columbia College, recommending the establishment of courses in meteorology and a meteorological laboratory in connection with the university. — *Reprinted from "Science" for Nov.* 29, 1895.

in motion on a rotating surface would be deflected to the right in the northern hemisphere, and that a pressure in that direction would therefore accompany any effort to make the body move in a straight line. In consequence of this deflection a belt of low pressure must exist around the earth at the equator and areas of low pressure at the poles with special areas of high pressure at the tropics. Among the equations of fluid motion Ferrel included the "equation of continuity," so called, but found that the general solution of the problem as thus stated analytically was impracticable; he therefore took as a special solution the observed pressures and temperatures all over the globe and showed what the relative motions must be both for the lower winds and the upper atmospheric currents. He then proceeded to a discussion of the temperatures, pressures, and winds that must be experienced within a region of abnormally high or low pressure, such as we now call cyclones or anti-cyclones. He derived the formula connecting the intensity of the barometric gradients with the winds that cut across them diagonally.

Ferrel's next memoir took up the thermodynamic problems, especially those that Espy had seen to be important factors in the development of our thunderstorms, showing that ascending air expands and by virtue of its expansion is cooled throughout its whole mass to an extent easily calculated by the laws of thermodynamics, and that when cooled below the dew point a formation of fog and cloud must result, giving rise to an evolution of heat and a delay in the cooling process, so that the moist air is warmer than the dry air would have been. Thus a cloud once formed becomes a centre of aspiration, so that clouds and storms grow as long as they are supplied with uprising currents of moist air. Ferrel reduced to formulæ and figures the general doctrines of Espy and showed them to be perfectly applicable to a certain class of our storms, namely, those in which the ascent of air is sufficiently rapid to render the radiation of heat and the mixture with surrounding air matters of secondary importance.

The general treatise of Prof. Ferrel entitled "Recent Advances in Meteorology," published by the Signal Office in 1885, gives most of his earlier results with many revisions and new ideas.

Very similar results were published by Oberbeck in 1882 and 1888, employing more elegant mathematical methods and advancing a step beyond Ferrel's first publications. It may, however, be stated that the general solution of the hydrodynamic equations presupposes a definite knowledge of the distribution of temperature or of density in the atmosphere; and, of course, the solutions given by Oberbeck and Ferrel are intended to apply only to the atmosphere as we observe it.

The thermodynamic phenomena attending the ascent and descent of the air have been treated analytically by many authors, such as Sir William Thomson, Reye, Chambers, Hann, Guldberg, and Mohn; within the last few years this subject has been worked out in a very elegant, graphic way by Hertz and von Bezold.

The memoir of Hertz considers only adiabatic changes, while the memoir of Bezold considers the changes that are not strictly adiabatic. It is evident on a slight consideration that the quantity of heat within a given mass of

air is continually changing by reason of several processes: *first*, the direct absorption from the sun; *second*, radiation to colder objects; *third*, the loss by convection of heat attending the precipitation of rain or snow; *fourth*, the gain by convection attending evaporation from the earth into the air; *fifth*, the process of mixture that is constantly going on. Therefore, atmospheric processes are by no means always adiabatic, and Bezold's graphic methods enable us quickly to solve any problem that may be presented. Bezold and Helmholtz have agreed in adopting and recommending the term "potential temperature" as defining the temperature that a mass of gas would have if brought to a normal pressure, without loss or gain of heat.

Helmholtz added to our knowledge of atmospheric movements by his studies on the conditions of stability among masses of air that have a discontinuous motion, such as two vortex rings encircling the earth in different latitudes and having different temperatures. In general, stable equilibrium is possible only when the warm ring is on the polar side of the cold ring.

A pupil of Helmholtz, Prof. Diro Kitao, of the Imperial Academy of Agriculture of the University of Tokio, has made an elaborate study of the forms of motion that attend the meeting of two horizontal currents, which then pile up and roll back on themselves.

Finally, Helmholtz has given us very remarkable memoirs on waves in the atmosphere and the distribution of energy in the winds and the ocean waves. Moeller, Sprung, Hann, Wien and others have elaborated the ideas thus contributed.

The so-called "convection theory of storms" that we call Espy's, assumes that the latent heat of vapor is the maintaining power and that the original ascent of the moist, warm air is due to its buoyancy. Therefore we could have no continued cyclonic motion without ascending moisture and clouds and rain. But the other studies have, I think, put it beyond doubt that there is another equally important cause at work, which undoubtedly is the fact that the upper air flowing northward from the equator as a return trade is slowly cooling by radiation and descending. It eventually reaches the earth here and there in spots which are small areas of clear sky in the tropical regions, but are large areas of cold, dry air and high pressure in northern latitudes. If the air is cooled by radiation faster than it is warmed up by the compression attending its slow descent, then it descends as clear, cold, and dry air, and only after reaching the earth's surface does it begin to warm up again in the daytime faster than it can cool at night. As this dry, cold air under-runs the moist, warm air at the earth's surface, or as two areas of high pressure flowing toward each other must lift up the lighter air between them and set it into cyclonic rotation, we must, therefore, recognize the general conclusion that Espy's aspiration cyclone as developed by Ferrel is not the only form of cyclone, but that those due to descending cold air and, therefore, having the general circulation of the atmosphere as their fundamental cause are equally entitled to consideration.

To this last and latest development from the theoretical side I need only add that the study of the motions of the clouds has enabled me to assert confidently that there is no form of motion known to the student of the mechanics of fluids but what is to be found beautifully illustrated in some

important phenomenon of the atmosphere. I may give one illustration of this statement.

All have seen the beautiful standing waves on the surface of a little stream of water flowing over a rocky bed. The theoretical study of these waves began with Bidone early in this century and has been especially prosecuted by Bazin and Boussinesq, in France, and Sir William Thomson, in Scotland. Precisely similar waves must occur in the atmosphere, but can only become visible to us by the formation of clouds at the summit of each wave if the air rises high enough. Invisible standing waves exist over our heads all the time. It was my good fortune to make an extensive series of observations on a remarkably well-developed system of standing waves capped by clouds, which perpetually extend from the summit of Green Mountain, on the Island of Ascension, to the leeward for a hundred miles under the influence of the steady southeast trade wind. These become invisible when the air becomes a little cooler or dryer, and consequently they actually disappear every night only to reappear as regularly every day.

But I need not dwell any longer on the relations of the theoretical and the actually observed motions of the atmosphere. Our interest in the meteorological or dynamical theories and their application to the atmosphere is not inferior to our interest in any other physical science.

The possibility of making accurate long-range predictions of the weather and the seasons is recognized as an ultimatum that should fire the zeal of every young physicist.

Meteorology has advanced far beyond the stages of observation and generalization. It has had its Newton, Laplace, Dove, Espy, Ferrel, Oberbeck, and Helmholtz and Thomson. As an application of mathematical physics it outranks all other branches of science in its universal importance and its difficulty. Why should it not be recognized as worthy of study in our universities?

COURSE OF INSTRUCTION IN METEOROLOGY.

The following courses in the Department of Meteorology are designed to give a complete review of the present condition of that science, and are therefore necessarily extended through four years; but the series of lectures is so arranged that each of the four divisions is complete within itself; each course presents a view of a branch of the subject such as may be desired by a large number of students who need this information in connection with other branches of knowledge to which they are specially devoting themselves.

Students who intend to take the degree of Ph. D. in meteorology, and who therefore make this the major subject in connection with several other minor courses, must pursue the whole four years' course. Those who merely desire to understand observational meteorology will probably find the first year's course sufficient. Those who desire to do original work in climatological study should also take the second year. The third year's course is designed for those who wish to perfect themselves in methods of making local weather forecasts. Finally, the fourth year's course summarizes the present state of our knowledge of the mechanics and physics of the atmosphere.

FIRST YEAR. — Observational Meteorology. The methods of observation; the simpler instruments, their errors, corrections and reductions; the theory and use of self-registers; the forms of record and computation; personal diary of the weather.

Time. — About eighty lectures, or two hours a week, as also eighty other hours of personal investigation of instruments and their exposure.

Concomitant Studies. — Algebra and trigonometry are the necessary preliminaries to this course. Elementary laboratory physics, as illustrated by Hall and Berger's text-book, is desirable as a preliminary, but may be pursued as a concomitant study. The German language is earnestly recommended as a concomitant. The differential and integral calculus should be studied as preliminary to the fourth year.

SECOND YEAR. — Climatology, both local and general; statistical meteorology, generalizations, averages, periodicities, irregularities. The relations of climate to geology, to vegetation, to animal life, and to anthropology.

Time. — About forty lectures and four hours weekly given to the investigation of special problems proposed in each lecture.

Concomitant Studies. — Students should familiarize themselves with the use of logarithms; the method of least squares; the laws of chance; the details of physical geography, orography, geology, and ocean currents; the physiology of plants and animals; the distribution of species; physical astronomy, especially that of the earth, sun, and moon; terrestrial magnetism; the chemistry of the atmosphere; the biology of atmospheric dust. Physical laboratory work on radiation, conduction, and absorption of heat, on the condensation and evaporation of vapor, and on elementary electricity, is recommended. The study of German, the calculus and analytic mechanics should be continued as preliminary to the remainder of the course.

THIRD YEAR. — Practical Meteorology; the daily weather chart; the empiric laws of weather changes as dependent on meteorological data and on the arrangement of continents, plateaus, mountains, oceans, etc., weather types and typical weather charts; predictions of daily weather, storms, and general predictions of seasonal climates; verification of predictions.

Time. — About forty lectures and about five hours a week additional in verifying predictions.

Concomitant Studies. — Methods of chart projection; experimental laboratory work in both steady and discontinuous motions of fluids and gases; mathematical and experimental electricity; the laws of refraction and interference of light; elementary hydrodynamics and thermodynamics; differential equations and definite integrals; the German language.

FOURTH YEAR. — Theoretical Meteorology. Insolation. The absorption, conduction, and radiation of heat by the air and by the earth. The thermodynamics and physics of the atmosphere; the graphic methods of Hertz and Bezold. Convective equilibrium, as applied to the atmosphere of the sun by Lane, and to that of the earth by Sir William Thomson (Lord Kelvin), and their successors. Motion on a rotating globe; Ferrel's and other simple approximate relations between baric gradients and the wind and temperature; Ferrel's general circulation of the atmosphere and his cyclones and pericyclones and tornadoes. Galton's cyclone and anti-cyclone. Fourier's most general equations of gaseous motions. Oberbeck's general

circulation. Helmholtz's horizontal rolls. The investigations of Diro Kitao, Guldberg and Mohn, Marchi, Boussinesq, A. Poincaré, Sprung, Siemens, Moeller, Ekholm, Ritter, Lindeloff, Margules and Hermann into the motions of the atmosphere. Viscosity and discontinuity. The possible special solutions of the general equations of fluid motions that apply to the true atmospheric circulation, both on the earth and on the other planets. Atmospheric tides; theories of Laplace, Ferrel, Rayleigh, Margules, A. Poincaré. Theories of atmospheric electricity.

Time. — Eighty lectures and an additional four hours a week given to special reading and investigation and to the preparation of the final thesis, as closing the four years' course.

Concomitant Studies. — Riemann's "Differential Gleichungen"; Auerbach's "Hydrodynamics"; Lamb's "Hydrodynamics" (new edition); physical laboratory work in gaseous motions, optical and electrical phenomena.

THE METEOROLOGICAL LABORATORY.

In order to carry out an ideal course in meteorology it is necessary to not merely study lectures and text-books but the current daily weather maps; to practise the use of instruments and to keep weather records; to investigate special questions in local climatology, and to personally explore the atmosphere.

In the meteorological laboratory the student should investigate experimentally questions that arise in relation to the motions of the atmosphere, which includes almost every pertinent form of experiment in the motions of fluids and gases. Provision should also be made for the study of such optical phenomena of the atmosphere as refraction, absorption, interference, scintillation, mirage, and sunset colors.

This laboratory should also provide for study and practice with self-registers, the study of the thermodynamics of the air and aqueous vapor; the determination of the amount of heat received from the sun; the continuous records of atmospheric electricity, terrestrial magnetism, earth currents, the tides and earthquakes.

The laboratory should also provide mathematical apparatus or mechanical devices by which complex questions in the motion of the atmosphere may be solved.

Facilities should be given for the study of atmospheric dust, especially in its relation to the temperature of the air and to the formation of clouds and rain.

The laboratory should contain a working library and bibliography.

*Percentage of Mean Cloudiness and of Mean Sunshine for the California Weather Bureau Stations, and Average Number of Clear Days.** — The data from which the following tables of the percentage of cloudiness and sunshine were taken are a series of monthly charts issued by the Chief of the Weather Bureau under date of June 20, 1891.

* Prepared and furnished by James A. Barwick, Director of the California State Weather Service.

The introductory remarks made in reference to the charts fully explain the manner in which the data were prepared. A column of clear days for each station has been added by the director of this Service, and the percentage of sunshine, being the complement of the cloudiness, although not given in the published charts above referred to, is easily obtained, as the percentage of sunshine is the difference between the percentage of cloudiness given and total cloudiness, which is 100 per cent. It is therefore self-evident that if a given place has 50 per cent of cloudiness there must then be 50 per cent of sunshine, etc. The introductory remarks made in placing the charts or maps of mean cloudiness before the public are as follows: —

"The average percentage of cloudiness at the Weather Bureau stations in the United States is graphically shown by twelve charts. The data have been drawn from eighteen years of tri-daily eye observations — 1871–1888 — except at stations established subsequent to the first-named year. Total cloudiness is represented by 100 per cent, and an absence of clouds by zero (0).

"The value of these data, however, is in their application to climatological questions, and in the fact that they show indirectly the relative amount of sunshine, which is an important element in all investigations bearing upon the relation of climate to crop production.

"It has been assumed — a reasonable assumption, in which no large error can obtain — that the complement of the cloudiness will be the sunshine. Sunlight and cloudiness have both an important influence on health and many agricultural and commercial interests. The average quantity of cloud, mist, and rain to be found in any locality determines, to a great extent, the suitableness of that locality as a habitation for persons requiring a maximum amount of sunlight and opportunity for exercise in the open air. The medical profession, notwithstanding the importance of the question, is yet without standard cloud maps for the United States.

"Due proportion of sunlight, warmth, and moisture is necessary to produce healthy vegetation, and insure the ripening of all growing crops in certain months of the year. Cloudiness is also an important element, since the presence of clouds naturally results in screening the earth from excessive insolation; or, in other words, in diminishing the heat received by vegetation from the direct rays of the sun. So, also, acting as a screen, it prevents in a measure the radiation of heat from the earth into space, and thus materially tends to modify and reduce the diurnal range of temperature, so that growing vegetation is not subject to as great cold as would otherwise obtain during the night; nor, on the other hand, does it receive the full amount of solar heat by day.

"The phenomena of cloudiness are, moreover, so interwoven with the more complex phenomena of diurnal variations of air pressure, temperature, vapor pressure, etc., and bear such intimate relationship to the distribution of rain, that the Weather Bureau Department feels warranted in reproducing a limited number of standard cloud maps of the United States for use by observers who are frequently called upon to furnish climatological statistics directly covered by the maps in question."

The following table gives the data drawn from the above-described charts: —

TABLE SHOWING THE PERCENTAGE OF MEAN CLOUDINESS AND SUNSHINE, ALSO THE AVERAGE NUMBER OF CLEAR DAYS, FOR EACH MONTH, AND FOR THE YEAR.

Month.	Eureka.			San Francisco.			Los Angeles.			San Diego.			Red Bluff.			Sacramento.			Keeler.			Fresno.		
	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.
	%	%		%	%		%	%		%	%		%	%		%	%		%	%		%	%	
January	53	47	5	48	52	12	32	68	17	39	61	13	45	55	14	42	58	13	27	73	21	43	57	9
February	41	59	5	46	54	10	37	63	14	41	59	10	43	57	12	33	67	13	25	75	20	45	55	14
March	48	52	4	46	54	12	42	58	13	48	52	9	39	61	14	35	65	16	26	74	20	38	62	12
April	56	44	4	42	58	12	47	53	11	46	54	10	40	60	12	34	66	15	26	74	19	40	60	18
May	45	55	4	40	60	14	43	57	12	54	46	7	35	65	16	24	76	21	21	79	22	24	76	21
June	39	61	9	40	60	12	39	61	10	50	50	6	20	80	23	14	86	25	11	89	26	11	89	25
July	28	72	6	46	54	8	29	71	13	47	53	8	10	90	28	5	95	30	15	85	26	4	96	30
August	17	83	6	43	57	9	25	75	16	40	60	10	6	94	29	3	97	30	11	89	27	6	94	30
September	24	76	13	34	66	13	23	77	17	38	62	11	11	89	25	9	91	26	10	90	28	6	94	25
October	40	60	15	32	68	15	26	74	18	39	61	13	21	79	27	17	83	23	14	86	25	16	84	22
November	45	55	5	38	62	14	26	74	19	35	65	14	34	66	18	28	72	19	25	75	21	24	76	18
December	50	50	2	47	53	13	31	69	18	37	63	14	48	52	12	35	65	13	26	74	19	47	53	8
Annual	40	60	78	42	58	144	33	67	178	43	57	125	29	71	230	23	77	244	20	80	274	25	75	232

The above table shows the advantages of California as a resort for invalids and weakly constituted people; in fact, for all who require plenty of sunshine and warmth during the winter, spring, and fall seasons of the year, so that plenty of outdoor exercise can be indulged in.

AVERAGE PERCENTAGES OF MEAN CLOUDINESS AND OF SUNSHINE BY SEASONS, AND THE AVERAGE NUMBER OF CLEAR DAYS.

DEDUCED FROM THE MONTHLY CLOUD CHARTS ISSUED BY THE UNITED STATES WEATHER BUREAU, WASHINGTON, D. C.

STATIONS.	WINTER.			SPRING.			SUMMER.			AUTUMN.		
	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.	Mean Cloudiness.	Mean Sunshine.	Average Number Clear Days.
	%	%		%	%		%	%		%	%	
Eureka	48	52	12	50	50	12	28	72	21	36	64	33
San Francisco	47	53	35	43	57	38	43	57	29	35	65	42
Los Angeles	34	66	49	44	56	36	31	69	39	25	75	54
San Diego	39	61	37	49	51	26	46	54	24	37	63	38
Red Bluff	45	55	38	38	62	42	12	88	80	22	78	70
Sacramento	37	63	39	31	69	52	7	93	85	18	82	68
Keeler	26	74	60	24	76	61	12	88	79	16	84	74
Fresno	45	55	31	34	66	51	7	93	85	15	85	65

It will be noticed by the above table that, during the winter season, Los Angeles and the interior of California south of the Tehachapi range of mountains have a greater percentage of sunshine than does that portion of California lying north of the above-named mountain range, except Keeler, which has the greatest percentage of sunshine at all times, except the summer season, when Sacramento and Fresno have a greater amount, while Red Bluff has the same as Keeler. The latter station (Keeler) has a greater annual percentage (80) of sunshine than any other portion of the State, as well as more clear days. In the Riverside region and surrounding sections of Southern California, the percentage of sunshine is very high, equally as much so as is reported from Sacramento. As no record of Riverside cloudiness has been regularly and continuously tabulated for a number of years past, the exact percentage of mean cloudiness and sunshine cannot be given, but enough is known of that region to be safe in claiming a higher sunshine percentage than for any other portion of California south of the Tehachapi mountains, excepting the desert region between Salton and Yuma, and Barstow and Needles, where it may average somewhat higher, and probably equals or exceeds the record of Keeler, which shows an average of 80 per cent of sunshine annually, and an average annual number of 274 clear days. Riverside and vicinity, during the winter season, has a larger percentage of sunshine than does the Sacramento or San Joaquin Valley, and equals those valleys in the spring, summer, and autumn percentages.

*A New Journal of Terrestrial Magnetism.** — With the January, 1896,

* From a circular recently issued by Dr. L. A. BAUER.

issue appears the first number of a journal devoted exclusively to terrestrial magnetism, and its allied subjects such as earth currents, auroras, atmospheric electricity, etc. No apology will be made for thus adding one more to the already over-large list of scientific periodicals. Indeed, it is this very multiplicity, making it possible for articles on terrestrial magnetism to appear anywhere but especially nowhere, that has made the need of concentration keenly apparent to the lovers of the science.

Primarily, the aim of this journal will be to create a broader sympathy and to afford an easier communication between widely separated workers in a field that is day by day receiving greater recognition and whose possibilities have not yet been fathomed ; secondarily, to increase the army of workers and of students.

Without doubt one of the chief wants of terrestrial magnetism to-day is a convenient channel for the timely and friendly interchange of ideas among the specialists in the science. *There is not a single journal at present that supplies this want.* The literature is in consequence scattered over many and miscellaneous periodicals, often well-nigh buried away in obscure publications or in such as are only accessible to a select few. In how far the journal will fulfil its prime purpose will depend principally upon the co-workers in the science. Now that terrestrial magnetism has an organ of its own — and that an international one — it behooves them to do their utmost to make the journal in every sense a success and thus to justify the important step terrestrial magnetism has taken.

It is also the firm belief that the journal should make it a special object to *increase* the ranks of the devotees by enlisting the interests of all the men of science who can contribute, whether directly or indirectly, towards the advance of the subject, such as astronomers, geographers, geologists, meteorologists, particularly, however, physicists and mathematicians. Here is a field full of interesting and fascinating problems, both of an experimental and of a theoretical nature, which can form the basis of legitimate and fruitful investigations. It is the intention, therefore, to have recognized authorities review the progress made in the various phases of the subject and to point out the direction in which further research is desirable and essential.

The day has gone by for studying the phenomena of the magnetized needle chiefly by reason of their possible value to the mariner and the surveyor. The higher view, ushered in by Humboldt and Hansteen, but most fully recognized by Gauss, that terrestrial magnetism is a subject worthy of the profoundest physical and mathematical study, has taken firm root and is steadily, though slowly, making progress. It gave birth to the famous Magnetic Union headed by Gauss and Weber. The epoch-making results which were the direct and indirect outcome of this magnetic association were equally beneficial to terrestrial magnetism and to science in general. It taught the physicist, among other things, how to make absolute magnetic measurements, and soon revealed to the scientific world that the earth's magnetism is in sympathic touch not alone with terrestrial but also with *cosmical* influences. Hence, gravitation is not the only bond that binds us in friendly union with our sister planets and our parent sun. The

magnetic needle thus has become a most promising instrument of research, not alone in terrestrial but also in cosmical physics. *No other mechanical means is so surely and so completely recording the physical history of terrestrial and cosmical changes as the self-registering magnetographs of our magnetic observatories, whereby the fitful tremors of the delicately suspendea magnetic needle are being indelibly fixed on the sensitized sheet.* "*On that paper*," *as Maxwell eloquently expressed it*, "*the never-resting heart of the earth is now tracing in telegraphic symbols, which will one day be interpreted, a record of its pulsations and its flutterings, as well as of that slow but mighty working* [*the secular variation*] *which warns us that we must not suppose that the inner history of our planet is ended.*" This extract suffices to give a hint as to the possibilities of geomagnetic investigations. In directing our eyes and enegies skyward to unravel the phenomena of the starry firmament, let us not forget that the earth, too, has its secrets and its mysteries that ought to be disclosed. Is it not *geophysical* observatories, *generously* equipped and endowed, that we especially need to-day?

The associate editors will be the following: —

Abbe, Cleveland, Professor in United States Weather Bureau, Washington, D. C.

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The contents of the first number are as follows:—

ON ELECTRIC CURRENTS INDUCED BY ROTATING MAGNETS AND THEIR APPLICATION TO SOME PHENOMENA OF TERRESTRIAL MAGNETISM . . *A. Schuster.*
DIE VERTHEILUNG DES ERDMAGNETISCHEN POTENTIALS IN BEZUG AUF BELIEBIGE DURCHMESSER DER ERDE . . . . . *A. Schmidt*, Gotha.
HALLEY'S EARLIEST EQUAL VARIATION CHART. Reproduced in fac-simile, for the first time, from a photograph furnished by Thos. Ward, Esq., of the chart in his possession. (Double-page half-tone, one fifth original size.) Text by *L. A. Bauer.*
LETTERS TO EDITOR:
On the Best Form for the Components of Systems of Deflecting Forces. A Discussion . . . . . *F. H. Bigelow; A. Schmidt*, Gotha.
Old Magnetic Declinations . . . . . *W. van Bemmelen.*
Some observations of the Magnetic Inclination in China . . . *W. Doberck.*
A WORD IN GREETING . . . . . *The Editor.*
NOTES . . . . . .
REVIEWS . . . . . .
RECENT PUBLICATIONS . . . . . .

"Terrestrial Magnetism" will appear four times a year, viz., during the months of January, April, July, and October. A volume will consist of four numbers, embrace about two hundred pages, and begin with the January issue.

Communications relating to the subject matter of the journal, as broadly defined and suggested by the title, are solicited. All languages that can be printed with Roman characters will be admitted. *One of the main languages, however, should be used whenever possible.* The manuscript must be legibly written, type-written when possible, *in Roman script*, and on one side of the paper only. If drawings (such as are absolutely essential) accompany the article they should be drawn in India ink and neatly finished.

It is earnestly recommended that communications intended for publication, especially foreign, be sent by *registered* mail. When communications have been, or are to be, published also in other journals, this should be stated. Publications intended for review should be sent in duplicate, when possible.

The editor cannot hold himself responsible for opinions expressed by contributors.

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Correspondence relating to subscriptions and advertisements is to be addressed to the University of Chicago, University Press Division, Chicago, Ill., U. S. A.

All other communications are to be sent to the responsible editor, L. A. Bauer, the University of Chicago, Ryerson Physical Laboratory, Chicago, Ill., U. S. A.

Royal Meteorological Society. — The opening meeting of the session was held in the new building of the Institution of Civil Engineers on Wednesday evening, Nov. 20, Mr. R. Inwards, F. R. A. S., president, in the chair, when a paper by Mr. J. Eliot, F. R. S., was read on "The Origin of the Cold Weather Storms of the Year 1893 in India, and the Character of the Air Movement on the Indian Seas and the Equatorial Belt, more especially during the Southwest Monsoon Period." This was really a discussion of the data contained in the Indian Monsoon Area Charts, the publication of which was sanctioned by the Indian Government for the two years 1893–94. Cyclonic storms are of frequent occurrence during both the northeast and the southwest monsoons, but they differ in many important respects. The storms of the southwest monsoon originate almost invariably over a sea surface, and travel in very variable directions, and occasionally develop into intense and furious hurricanes. The cyclonic storms of the northeast monsoon almost invariably originate over the plateau of Persia or Beluchistan, or in Northwestern India, and travel in an easterly direction at a velocity ranging between 15 and 20 miles per hour. These plateau-formed storms of the cold weather are the chief instruments of the distribution of the moderate rainfall essential for the great cold-weather wheat and other crops of Northern India, and are the chief sources of the snowfall of the western Himalayas. After giving an account of the more important cold-weather storms in January and February, 1893, and the results of the tabulation of the wind observations for the equatorial belt, the author describes the "burst of the monsoon." Mr. Eliot says that the evidence of the year 1893 is strongly in favor of the supposition that the southwest monsoon currents in the Indian seas are the direct continuation north of the equator of the horizontal movement of the southeast trade winds, and that the larger variations in the strength of the southeast trades near the equator during the monsoon period are reproduced in the monsoon currents in the Indian seas from June to September.

Mr. W. H. Dines showed a very interesting and instructive experiment illustrating the formation of the tornado cloud. The characteristic funnel cloud was readily seen extending from the tray of hot water to the mouth of

.he pipe at the top of the box, and when the draught was strong and the conditions favorable, a decided protuberance was observed on the surface of the water just under the end of the cloud. Mr. Dines is of opinion that the cloud is formed by true dynamic cooling, as the air saturated by the vapor from the hot water comes under the influence of the decreased pressure at the centre.

A paper by Mr. C. Davison, F. G. S., was also read, on "The Diurnal Variation of Wind Velocity at Tokio, Japan."

The second monthly meeting was held on Wednesday evening, Dec. 18, at the Institution of Civil Engineers, Great George Street, Westminster, Mr. R. Inwards, F. R. A. S., president, in the chair.

Mr. R. H. Scott, F. R. S., read a paper on "Some of the Differences between Fogs, as related to the Weather Systems which accompany them." In this it was shown that there are at least two distinct classes of phenomena described under the generic name of "fog." In the case of anticyclonic fogs no rainfall takes place, the temperature is low in the morning, and there is a considerable rise of temperature during the day, while in the case of cyclonic fogs, rainfall does take place, and the temperature is high in the morning, frequently approaching or even equalling the maximum for the day. Mr. Scott also investigated the cases of several well-marked fogs in London, and found that there was no direct relation traceable between the temperature accompanying them and the death rate.

Maj. H. E. Rawson described the results of his analysis of the Greenwich Barometrical Observations from 1879 to 1890, with special reference to the declination of the sun and moon.

A paper by Mr. S. C. Knott was read, giving the results of his meteorological observations taken at Mojanga, Madagascar.

Mr. Scott also exhibited some specimens of the illustrations in the "International Cloud Atlas," which is now being prepared for publication.

Avalanche Blast in Switzerland, Sept. 11, 1895.— In this JOURNAL for January, page 281, mention was made of the wind blast immediately preceding the ice-slip which occurred in Switzerland on Sept. 11, 1895. An article by Prof. Edward Brückner in *Himmel und Erde* for November, gives some additional information regarding this phenomenon. A forest in the neighborhood of the ice-slip was totally devastated. The trees were all thrown down in the direction of the wind, lying parallel to one another in the direction of W. S. W., while further to the south they were more S. W. The majority were uprooted. Even trees with a diameter of one and a half feet were torn up by the roots. In cases where a tree was growing in the lee of a mass of rock or of a hill, the unprotected part was simply broken off. Only a very few trees remained standing, and these were entirely under the shelter of the hills. Large numbers of the trees were stripped of their bark on the side which was struck by the wind, and many others had great pieces of bark torn off of them, evidently by flying stones and pieces of ice, so that they presented a wounded and spotted appearance.

The wind blast seemed to have been divided by an opposing mountain wall, for it threw the trees in different directions on the right and on the left of its course away from the ice-slip.

Another effect of the wind and of the flying stones is seen in the turf, which was torn up in many places, especially on the declivities where it was trodden by the cattle. In such places everything was covered with fine soil. In other places the turf was pressed down by the wind, blade being pressed against blade and all being bent down in the direction of the wind.

The damage done by the wind in overturning and uprooting the forest trees is shown in a photograph, the first of the kind ever taken. The violence of the blast may be judged by the following fact: An Alpine hut, together with four men who happened to be inside of it, was carried from two hundred to three hundred meters and dashed to pieces against the side of a hill, forest-covered on its top. Numerous beams were found here, broken off as if they had been matches, and the dead bodies of the four men. It is further reported that many objects, as well as several cattle, were dashed against the mountain side and, rebounding, fell to the ground some distance away from its foot.

Cyclonic Tracks near the Philippine Islands. — The Meteorological and Magnetical Observatory at Manila has issued a publication on the Tracks of the Cyclones which passed near the Philippine Islands during the year 1891. The tracks are shown on three charts, and there is a short description of the cyclones of each month. The disturbances of April, May, June, and July show a prevailing westerly and northwesterly course, while those of August and September show, in the majority of cases, the characteristic parobolic curve of the tropical cyclonic tracks. In November and December the westerly course predominates again. The cyclone of Dec. 20 seems to have started about 7° N., this being the nearest position to the equator noted during the year.

Signal Service Publications Wanted. — The editor of this Journal would like to communicate with any one who has the following publications of the Signal Service for sale: Professional Papers, Nos. 1, 4, 14, 17. Signal Service Notes, Nos. 2, 5, 12, 21.

BIBLIOGRAPHICAL NOTES.

TARR'S ELEMENTARY PHYSICAL GEOGRAPHY.

RALPH S. TARR, B. S., P. G. S. A. *Elementary Physical Geography.* 8vo. Macmillan & Co., New York and London, 1895. pp. xxxi., 488. Plates and charts 29, with nearly three hundred additional illustrations. Price $1.40.

Prof. Tarr, in his new work on physical geography, has certainly not slighted meteorology, for he has given it six whole chapters, embracing in all about 115 pages. This is an encouraging condition of things, and one which should please all those who are anxious to see meteorology given the place to which it is entitled in school study. Prof. Tarr's book is certain to be very widely used, for it is the first of its kind to treat physical geography in its modern aspect, and we may therefore hope that teachers who make use of it will see the importance of the study of meteorology, and will do what they can to make room for it in the hours which they may now have to devote to the general subject of physical geography.

The order of treatment of the subject of meteorology in this book is as follows: Chapter II., The Atmosphere; Chapter III., Distribution of Temperature; Chapter IV., General Circulation of the Atmosphere; Chapter V., Storms; Chapter VI., The Moisture of the Atmosphere; Chapter VII., Weather and Climate. The various important subjects under each of these general headings are considered in each chapter, and the illustrations given are abundant, and as a whole very good. The author has evidently taken considerable pains to search through the important works on meteorological subjects, and has collected from them the best illustrations for use in his own book. The chapter on "Distribution of Temperature" is especially well illustrated, with diurnal, seasonal, and annual temperature curves; Buchan's isothermal charts for year, January and July; several isothermal charts of the United States, etc. In the chapter on the "General Circulation of the Atmosphere," Prof. Tarr gives a classification of the winds which we venture to say is the most complete ever given in an elementary work on physical geography. The chief sub-divisions adopted are the same as those given by Dove, viz., "Permanent," "Periodical," and "Irregular" (Dove used the word "Variable" for these), but in its general features the classification follows the admirable one given by Prof. W. M. Davis in his "Elementary Meteorology." We fail to see, in this connection, why "Desert Whirlwinds" should be put under "Irregular Winds" rather than under "Periodical Winds," in which latter category land and sea breezes and mountain

and valley winds are placed. The chapters on "Storms" and on "The Moisture of the Atmosphere" are sufficiently full, and are well illustrated. Taking it all together, therefore, we may say that we are pleased to see so much space given to meteorology in this book, and to feel that the matters are presented, as a whole, in an attractive and in a suggestive manner.

It is easy for one who is especially concerned with the study of meteorology to find fault with the presentation of his subject in a book primarily devoted to geography, and for this reason we shall confine ourselves to a few general criticisms only. We think Prof. Tarr has made a mistake in making practically no mention of the study of the daily weather maps, for we believe that some systematic work on these is a most necessary preparation for the rational and thorough appreciation of the larger facts and principles of meteorology that are gradually discovered as a result of such work. It seems to us further that, had such an investigation been suggested at the beginning, and had some of the results which would thus be obtained been outlined, the general treatment of the subject would be less disconnected and unsystematic than it now seems. So much for general criticism. A few individual points need to be noted. The author has, naturally enough, been anxious to condense into the space he has devoted to meteorology as many matters of importance as possible, with the inevitable result that explanation is in many cases hurried and incomplete. Such matters, for instance, as the adiabatic warming of descending currents of air, and the resulting change in capacity for vapor, the explanation of the deflective effect of the earth's rotation, etc., do not seem to be sufficiently explained, even for the average teacher.

However, as we stated above, it is easy to find fault, and we do not wish to criticise any further what Prof. Tarr has, on the whole, done so well, and for doing which meteorologists should be grateful to him.

The illustrations are useful, and are mostly very good, the reproduction of a cumulo-nimbus, by Riggenbach, on page 102, being an especially successful one. We cannot say as much for the view of a tornado funnel-cloud, on page 104, nor for that of the damage done by the Lawrence, Mass., tornado of 1890, on page 105. An admirable feature of the book is the list of important references at the end of each chapter. We note two misprints. One on page 15, under Fig. 11, where "coet of Donati" is an obvious misprint for "*comet* of Donati," and the other on page 122, line 21, where "monsood" is an equally obvious misprint for "*monsoon*." On page 19 the final quotation marks at the end of the quotation from Prof. Newcomb have somehow slipped out.

We must confine ourselves simply to the meteorological portion of Prof. Tarr's book. Regarding the purely geographical side, we wish merely to state that the book is distinctly and decidedly a great advance on anything hitherto published on the subject, and it should be widely read and studied.

RUSSELL'S LAKES OF NORTH AMERICA.

ISRAEL C. RUSSELL. *Lakes of North America. A Reading Lesson for Students of Geography and Geology.* 8vo. Boston, Ginn & Co., 1895. pp. 125, pls. 23, Figs. 8. Price $1.50.

Lakes are of extreme interest to the meteorologist as well as to the geographer, and a study of their history and of their relations to climate, vegetation, etc., is one of the many attractive subdivisions of the general subject of meteorology open for investigation. As gauges of past climate, there are no better standards than large enclosed lake basins of continental interiors, and from a study of these basins we have already gained much information on the important subject of secular changes in climate. The climatic influence of lakes on their surroundings is also a subject in which much investigation needs still to be done, while the variations in the level of lake waters and of the composition of those waters, by seasons and years, affords another attractive field of research.

In Prof. I. C. Russell's new book on the "Lakes of North America" there is much that bears on the meteorological aspect of lakes, and it is for that reason that we mention the work here. Chapter IV. deals with the relations of lakes to climatic conditions, and in it the author considers fresh lakes and saline lakes, the material they have in solution, the chemical precipitates, etc. Chapter V. concerns the life histories of lakes, the latter being subdivided into lakes of humid regions and lakes of arid regions. This chapter contains many references to the climatic control of lake waters. Finally, in Chapter VI. on "Studies of Special Lake History," the history of Lakes Agassiz, Bonneville, Lahontan, and Mono is admirably summarized, and their evidence as to climatic changes set forth. The Monographs on Lake Bonneville, by Gilbert (Monograph I., U. S. Geol. Survey), and on Lake Lahontan, by Russell (Monograph XI., U. S. Geol. Survey), which are summarized in this chapter, are reports which should most certainly be familiar to all meteorologists on account of the information therein contained regarding the climatic history of the Great Basin.

There are numerous other facts of Prof. Russell's book which bear on the meteorological side of lake study, such, *e. g.*, as the sections in Chapter II., on the "Seiche," on the "Temperature," and on the "Influence of Lakes on Climate." In fact, for the purposes of climatic study, the meteorologist, although he may not find much that is new in the book, will certainly find the information given in an interesting manner. The latter point hardly needs mention, for whatever Prof. Russell writes is sure to be written in an interesting manner.

The book is attractively gotten up and well illustrated. The press work is excellent.